Engineering Design File

PROJECT NO. 23833

OU 7-13/14 In Situ Grouting Project Grout Delivery System

INEEL
Idaho National Engineering and Environmental Laboratory

EDF No.: 5102 EDF Rev. No.: 0 Project File No.: 23833

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5. **Purpose:** This engineering design file (EDF) provides the description, preliminary design criteria, and requirements for the grout delivery subsystem of the In Situ Grouting (ISG) Project for the pits and trenches in the Subsurface Disposal Area at the Radioactive Waste Management Complex. Information in this EDF is presented as a basis for a performance-type procurement of the ISG services and is intended to serve as guideline for procurement and cost estimating.

Scope: This EDF provides the system design requirements, design codes, pressure-retaining component quality requirements, and capacity requirements for the grout receiving hopper, shaker screen, low-pressure pump, high-pressure grout pump; and for the low- and high-pressure piping, hoses, drill pipe, and jets. Potential procurement and technical risks are also summarized. A suggested grout delivery system flow diagram is provided.

Acceptance Criteria: System component acceptance criteria are included in the quality requirements. Acceptance criteria for the project shall be included in the procurement specifications.

Results: Results are presented in the body of the EDF.

Conclusions Reached: Compliance with the project technical and functional requirements may be accomplished for the suggested grout delivery subsystem as presented in this EDF.

Recommendations: The procurement specification should include the equipment capacities as a minimum requirement. Code and quality requirement compliance for pressure-retaining components, as detailed in this EDF, will help ensure the high-pressure system will be built for safe operation.

6. Review (R) and Approval (A) and Acceptance (Ac) Signatures:
(See instructions for definitions of terms and significance of signatures.)

	R/A	Typed Name/Organization	Signature	Date
Performer/ Author	N/A	Al Cram, 3G23	Al Cram	9/27/04
Technical Checker	R	Daryl A. Lopez, 3K16	Daryl A. Lopez	9/29/04
Independent Peer Reviewer (if applicable)	R			
Approver	A	Tracy A. Langenwalter, 3K16	Tracy Langenwalter	9/29/04
Requestor (if applicable)	Ac	David F. Nickelson, PE, 3F20	David F. Nickelson	9/29/04
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ACRONYMS

API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
AWS	American Welding Society
BBWI	Bechtel BWXT Idaho, LLC
EDF	engineering design file
GDE	guide
ID	inside diameter
INEEL	Idaho National Engineering and Environmental Laboratory
ISG	in situ grouting
PSL	product specification level
RFP	request for proposal
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
TFR	technical and functional requirements

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OU 7-13/14 In Situ Grouting Project Grout Delivery System

1. PURPOSE

Design criteria in this engineering design file (EDF) is presented as a basis for a performance-type procurement of in situ grouting (ISG) services and is intended to serve as a guideline for procurement and cost-estimating purposes. This EDF includes the design parameters, design codes, quality requirements, and capacity requirements for the grout delivery subsystem of the ISG system. A suggested grout delivery flow diagram is also provided. This design work is generated in support of the conceptual design report as defined in Guide (GDE)-51, "Construction Project Management," Section I.E.

2. BACKGROUND

Grouting in the Radioactive Waste Management Complex (RWMC) Subsurface Disposal Area (SDA) will be conducted with one or more large hydraulic excavators (i.e., trackhoes) that deploy a roto-percussion drill to inject grout into the waste under high pressure. A high-pressure grout pumping system will be integrated with the trackhoe drill. Operations, maintenance, monitoring, and radiation control systems will be deployed to support field operations. In situ grouting work will be subcontracted to provide and place grout to the project's specifications.

To minimize the risk of mobilizing contaminants within the waste zone, Bechtel BWXT Idaho, LLC (BBWI) has chosen a single-phase, nondisplacement, jet grouting approach that does not require injection of high-pressure air or free water. Grouting will be accomplished by driving a drill through the overburden into the waste zone and injecting grout at pressures up to 8,000 psi through nozzles in the drill stem as it is withdrawn. The injected grout will create a series of interconnected columns that form a solid monolith of soil, waste, and grout. During this process, excess grout is returned to the surface along the outside of the drill stem.

This project is anticipated to be accomplished in seven years. The first year, one drill rigs will be used, and the second through seventh year, three drill rigs are anticipated to be used. This design is based on the required jet-grouting capacity of three drill rigs operating simultaneously.

The contaminant stabilization grout is anticipated to be a cementacious type containing sand, cement, ground blast furnace slag, silica fume, water, and two or more admixtures. Additional grout demonstration tests are being planned for determination of the final grout recipe. Foundation grout is anticipated to be sand, cement, and water. The grouts used as a basis for this engineering evaluation are likely to be different than the grout mix recipe ultimately chosen.

In 2001, there was an accident at RWMC during an ISG test. A subcontractor employee was struck by metal from a ruptured high-pressure fitting. When the grouting system pressure was raised, the fittings connecting the high-pressure pump to a pressure flow sensor failed, resulting in flying metal. An investigation showed that an underrated elbow fitting was used in the grout system. The pass down of system requirements and quality oversight of the subcontractor did not prevent or detect the equipment deficiency.

EDF-4897, "Evaluation and Response to the Grout Accident Investigation Report for the OU 7-13/14 Early Actions Beryllium Encapsulation Project," was prepared to evaluate the information from the grout accident report (DOE/ID-10968, *Type B Accident Investigation Board Report, Grout Injection*

Operator Injury at the Cold Test Pit South, INEEL) specific to the Early Action ISG project, and provide a response to the report issues on how the project has addressed the issues of providing a safe jet grouting operation. The evaluation provided in EDF-4897 is also applicable to the Operable Unit 7-13/14 ISG Project.

Special controls will be implemented by the project to ensure the integrity of the high-pressure grout system. The specific controls are based on controls recommended following the accident. These controls will be adequate to protect against failure of the high-pressure grouting system. The controls include the following:

- Subcontractor submits a pressure design report documenting the design of the pressurized components and system (will be included in the request for proposal [RFP])
- Subcontractor submits a pressure design verification report documenting that the system meets the design (Section 8.2.2)
- Quality control requirements on pressure retaining equipment ratings, assembly, and pressure relief equipment (Section 8.2)
- Subcontractor testing to demonstrate pressure test and pressure relief system performance (EDF-5155, Section 7.2.4, and Section 7.2.6 of this EDF)
- Design requirements to operate at 20% below rated pressure (Section 7.2.6), use new hoses and fittings (Section 7.2.7), perform assembly testing (EDF-5155, "OU 7-13/14 In Situ Grouting Project Operations, Maintenance, and Logistics," Section 7.2.4), provide pressure relief capability (Section7.2.6), automated grout pump shutoff (Section 7.2.4), hose restraint and whip checks (Section 7.2.8), and preventive maintenance (Section 8.2.4)
- Inspections and evaluations of all high-pressure components for wear (Section 8.2.4)
- Project oversight of grouting contractor's pressure equipment and quality program (Section 8.2.6).

3. SCOPE

This EDF provides a description, design criteria, and requirements for the ISG Project grout delivery subsystem, consisting of the following:

- Grout receiving hopper
- Shaker screen
- Low-pressure pump
- Low-pressure piping to the high-pressure pump
- High-pressure grout pump
- High-pressure piping

- Hoses to the drill string swivel
- Drill stem and drill bits.

Calculations are shown in EDF-5135, "OU 7-13/14 In Situ Grouting Project Grout Storage and Mixing," Appendix A for sizing the high-pressure grout pump.

Although the design of this equipment will be subcontracted to the ISG grouting subcontractor, certain criteria (such as design codes, pump capacity, component quality requirements, and safety requirements) should be defined in the RFP by the contractor.

4. REQUIREMENTS

Technical and functional requirements (TFRs) are developed for a project before the conceptual design process by project staff and approved by the project engineer. TFR-267, "Requirements for the OU 7-13/14 In Situ Grouting Project (Customer, Project, and System)," was developed as high-level requirements for ISG. During the conceptual design process, the TFRs are reviewed and investigated by the conceptual design engineers. The conceptual design approach is then developed from the investigation and analysis of these customer requirements and the conceptual design is then created. The engineer then develops and specifies design criteria unique to the individual subsystem for subsequent detailed design.

The TFRs unique to the individual subsystems are listed in TFR-269, "Requirements (Assumptions) for the OU 7-13/14 In Situ Grouting Project." The requirements applicable to the ISG grout high-pressure delivery subsystem, drill pipe and bits, hoses and fittings, and jets are listed in this section and Section 7.2. Each requirement is followed by a brief discussion of how the requirement is to be met.

4.1 Grout High-Pressure Delivery Subsystem

Provide a high-pressure pump.

See Section 7.2.4.

Provide high-pressure relief capability (EDF-4897).

See Section 7.2.6.

Be capable of providing a trickle flow to the injection nozzles while relocating to a new injection location.

See Section 7.2.4.

Be able to interface with the hose management components.

The hose management components are the hose fittings, hoses, and hose connections on the drill string swivel and on the high-pressure pump. See Section 7 for interfaces.

Provide a vehicle for delivering the grout.

The vehicles for delivering the grout from the agitator tank to the grout receiving hoppers shall be ready-mix style trucks.

Be able to be certified for 10,000 psi.

See Section 7.1.

Be able to be hydrostatically tested after component change.

See EDF-5155, Section 7.2.4.

Be able to predict high-pressure hose change before failure.

See Section 8.2.4.

Provide for high-pressure pump continuous monitoring.

See EDF-5155, Section 10.1.

Be diesel powered.

See Section 7.2.4 and Section 7.2.14.

Be able to adjust grout mix for different soils.

The ability to adjust the grout recipe pertains to the batch plant. The rate of grout injection shall be able to be adjusted for different recipes by changing the jet size and varying the injection time for each hole.

Provide capability to filter system to screen rocks and other solids.

See Section 7.2.1.

Be able to provide grout that shall remain in a slurry for up to two hours.

The grout recipe shall contain a set retarder to keep the grout from solidifying for a minimum of two hours. The grout recipe is the subject of EDF-5146, "OU 7-13/14 In Situ Grouting Project Grout Selection."

4.2 Drill Pipe and Bits

Provide a bit change box.

See Section 7.2.15.

Provide a bit cavity.

See Section 7.2.13.

Determine acceptable diameter.

See Section 7.2.10.

Determine acceptable deflection.

See Section 7.2.10.

Be able to recover from stuck pipe.

The stuck drill string recovery procedure is included in EDF-5155, Section 10.1.

Determine acceptable drill pipe length.

See Section 7.2.10.

Provide threads that tolerate misalignment when changing.

The standard drill stem threads can tolerate some misalignment when the pin is stabbed into the box of the tool joint; however, the drill stem elements will come into alignment as the joint is made up. Also see Section 7.2.11.

Provide drill pipe storage.

See section 7.2.10.

Determine drill bit selection criteria.

See Section 7.2.13.

Provide for drill bit storage.

See Section 7.2.13.

Provide capability for drill bit redressing and repair.

See Section 7.2.13.

Do not use drill pipe joiners.

See Section 7.2.10.

4.3 Hoses and Fittings

Provide capability to be hydrostatically tested.

The hoses and fittings shall be hydrostatically leak tested before each use along with the drill stem connections, bleed valve, and rupture disc fittings at the high-pressure pump (see Appendix A). The testing process and test acceptance criteria is described in EDF-5155, Section 7.2.4.

Provide capability for hose changeout.

See Section 7.2.7.

Provide capability for certification and pedigree of components.

The hose-end connections shall be required to have material traceability and associated hydrotest reports from the manufacturer as detailed in Section 8.2.

Do not use hydraulic fittings, which is a solids issue.

See Section 7.2.7.

4.4 Jets

Provide methods for jet selection.

The jets shall be selected by the subcontractor. Also see Section 7.2.13.

Determine jet parameters (size, slope, and angle).

See Section 7.2.13.

Provide method for changing jets.

See Section 7.2.13.

Provide method to measure jet wear.

See Section 7.2.13.

Provide method to address jet plugging.

Unplugging of jets is addressed in EDF-5155, Section 10.1.11.

Determine nominal revolutions per minute.

This will be determined during the subcontractor cold testing operations. See EDF-5155.

Use standard pipe thread (misalignment and dirt).

See Section 7.2.13.

5. SYSTEM CLASSIFICATIONS, CATEGORIZATIONS, AND DETERMINATIONS

An ISG safety authorization basis document is being written to address the issue of system safety classification; however, the following determination will be assumed until the document is issued:

The grout receiving hopper, vibrating screen, low-pressure pump, and low-pressure piping going to the high-pressure pump inlet are not safety class and, therefore, may be purchased as consumer grade.

The high-pressure pump, downstream piping, and pressure retaining drill string components are assumed to have a safety classification of safety significant because of the 10,000-psi maximum rated working pressure (INEEL/EXT-03-00316, *Feasibility Study Preliminary Documented Safety Analysis for In Situ Grouting in the Subsurface Disposal Area*).

The subsystem components are International Building Code Category I temporary facilities in regard to importance factors. The mapped seismic spectral accelerations for RWMC are as follows:

- Short period acceleration value is 0.357
- One-second acceleration value is 0.131.

6. ASSUMPTIONS

The following are assumptions for the grout delivery system for the ISG Project:

- The average grout column height to be used for design is 13 ft, equating for an average 15-ft depth to bedrock (from the trench depth map) minus 2 ft of overburden (EDF-4013).
- Grout volume to be injected is 13.6 gallon/ft of column height (INEEL/EXT-02-00233, Section 5.4 from grouting 12 holes).
- The design production rate will be one column (13 linear feet) per 3.5 minutes of grouting using three jets in the drill stem bit.
- The pump will be capable of supplying 50 gallon/minute (191 liter/minute) based on the capability of grouting 13 linear feet of waste in 3.5 minutes as described in the previous assumption.
- The operational process of the grouting will be refined during startup testing at the cold test pit north. This will include the drill bit rotational speed, step height, and other operational parameters.

7. DESIGN CRITERIA

7.1 Applicable Design Codes and Standards

Although specific American Petroleum Institute (API) specification requirements have not previously been applied to high-pressure grouting equipment at the Idaho National Engineering and Environmental Laboratory (INEEL), the use of pressure retaining components complying to the API specifications will ensure the components are designed, manufactured, and hydrostatically tested for the 10,000-psi maximum rated working pressure; one of the pressure classes listed in API Specification 6A, *Specification for Wellhead and Christmas Tree Equipment*, Paragraph 4.2.1.

Previously, the normal working pressure of high-pressure grouting equipment was 6,000 psi (DOE/ID-10968, Paragraph 3.1.4), which did not fit into any of the API pressure class ratings. Therefore, the API codes were not used. DOE Order 440.1A, Attachment 2 Section 20.c, “Pressure Safety,” includes the following requirement relating to national consensus codes:

> When national consensus codes are not applicable (because of pressure range, vessel geometry, use of special materials, etc.), implement measures to

provide equivalent protection and ensure safety equal to or superior to the intent of the ASME code. Measures shall include the following:

(1) Design drawings, sketches, and calculations shall be reviewed and approved by an independent design professional. Documented organizational peer review is acceptable.

(2) Qualified personnel shall be used to perform examinations and inspections of materials, in-process fabrications, non-destructive tests, and acceptance tests.

(3) Documentation, trace ability, and accountability shall be maintained for each pressure vessel or system, including descriptions of design, pressure, testing, operation, repair, and maintenance.

DOE Order 414.1B, Part 4.a.2, "Quality Assurance," requires use of voluntary national or international consensus standards where practicable and consistent with contractual or regulatory requirements and identity of the standard used. Considering this requirement, components complying with an international consensus code equivalent to the specified API or American Society if Mechanical Engineers (ASME) code may be provided if approved by BBWI.

If high-pressure components do not meet API standards, the components should comply with the design methodology in the ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, and Appendix 4. Components designed to the ASME code for a 10,000-psi working pressure are almost nonexistent, whereas components designed to the API codes are readily available.

The subcontractor shall implement measures to provide equivalent protection and ensure safety equal to the API or ASME codes consistent with DOE Order 440.1A. This EDF lists the applicable API specifications where API specifications can be readily applied and the components are industry standard. Fittings and hoses manufactured to foreign codes equivalent to the API and ASME specifications may be used as approved by the contractor on a case-by-case basis.

Special controls will be implemented by the project to ensure the integrity of the high-pressure grout system. These controls are identified in EDF-4897.

7.1.1 Low-pressure retaining system components (i.e., 150 psi and under)

Low-pressure retaining system components (i.e., 150 psi and under—ASME Code B31.3, *Process Piping*, for Category D fluid service). Pressure retaining system components for pressures between 150 and 2,500 psi—ASME Code B31.3 for normal fluid service.

7.1.2 Grout Receiving Hopper, Shaker Screen, and Low-Pressure Pump

The grout receiving hopper, shaker screen, and low-pressure pump are to be designed to vendor standards. Piping connecting the low-pressure pump to the high-pressure pump inlet—ASME B.31.3 for category D fluid service.

7.1.3 High-Pressure Pump

The high-pressure pump shall be to be designed to vendor standards with additional safety features as specified herein.

7.1.4 High-Pressure (10,000-psi Working Pressure) Retaining System Piping Components

The high-pressure retaining system piping components—API Specification 6A and API RP 17B, *Recommended Practice for Flexible Pipe*—are delineated as follows:

- Equipment designed with internal API-threaded end and outlet connections are limited to 1/2 in. NPS in accordance with API Specification 6A, Paragraph 4.2.1.b
- Integral equipment end and outlet connections—API Specification 6A, Paragraph 10.2
- Test, vent, injection, and gauge connections—API Specification 6A, Paragraph 4.4.5
- Unions and swivel joints—API Specification 16C, Paragraph 9.6
- End and outlet connections—API Specification 16C, Paragraph 9.5
- High-pressure (10,000-psi working pressure) flexible lines (hoses) are for cement service—API RP 17B.

7.1.5 Drill Pipe

Drill pipe—API Specification 5A, *Specification for Casing, Tubing, and Drill Pipe.* Drill pipe rotary-shouldered connections—API Specification 7, *Specification for Rotary Drill Stem Element.*

7.1.6 Drill Pipe Tool Joints, Drill Stem Subassemblies, Drill Bits, and Drill Stem Swivels

Drill pipe tool joints, drill-stem subassemblies, drill bits, and drill stem swivels—API Specification 7 and API RP 7G.

7.1.7 High-Pressure System Safety (Relief) Valves and Rupture Disk

High-pressure system safety (relief) valves and rupture disk—ASME Code, Section VIII, Division 1, Paragraph UG-125 through UG-137 and Appendix M. API RP 520 provides guidance for conditions of design and performance.

7.1.8 Diesel Generator

The diesel generator shall be supplied as consumer grade.

7.2 System Design

7.2.1 Shaker Screen

A vibratory shaker screen is suggested to screen the grout as it is dumped into the grout receiving hopper from the ready-mix trucks. This screen should be capable of screening out any particles larger than approximately one half the size of the drill stem jets, which are 2.4 to 3 mm. A duplex strainer is also recommended in the line leading into the high-pressure grout pump to screen any large particles that may have been left in the receiving hopper. A differential pressure gauge across the duplex strainer should be attached to an audible warning device to warn if the strainer is plugging.

The shaker screen should be an oil field mud type designed and constructed to fit the receiving hopper, or the receiving hopper shall be designed to fit the screen. If the shaker screen is used, it must be capable of being relocated (rolled on rails) away from the top of the receiving hopper to facilitate maintenance and cleaning using a hand held spray wand.

7.2.2 Grout Receiving Hopper

The grout receiving hopper shall receive grout from the ready-mix trucks and is anticipated to have an integral low-pressure pump. The low-pressure pump would be capable of recirculating the grout and pumping the grout to the high-pressure pump suction connection.

7.2.3 Low-Pressure Pump and Low-Pressure Line

The low-pressure pump, which is integral with the receiving hopper, is anticipated to be capable of providing flow through the low-pressure piping and duplex strainer to the high-pressure pump inlet at the high-pressure pump manufacturer's recommended pressure (assumed to be approximately 50-psi minimum).

7.2.4 High-Pressure Pump

The high-pressure pump is anticipated to be an off-the-shelf, skid-mounted pump on a truck bed. The pump should be diesel engine-driven, including a control panel, and should have all safety features required in this EDF built in where possible.

The high-pressure pump is anticipated to be a triplex diesel-powered positive-displacement pump capable of delivering 50 gallons/minute (191 liters/minute) at 8,000 psi (552 bar) measured at the pump outlet. For safety reasons, the pump must be equipped with an automatic pump-clutch tripout upon over-pressurization. The clutch between the motor and pump must be capable of being locally manually disengaged and remotely disengaged by the driller in the trackhoe cab or by the high-pressure pump operator at the pump control panel. The discharge fitting of the high-pressure pump will connect to the fittings of interconnecting piping.

The high-pressure pump must have a sufficiently low gear at idle or other method to produce a trickle flow of grout to prevent dirt from entering the jets when moving from one hole to another and to keep the grout from setting up in the nozzles. The trickle flow is defined as greater than 100 cc per minute and less than 2,000 cc per minute. Excess grout returns will be produced if the pump does not have a trickle flow capability as experienced during the beryllium block grouting project.

The high-pressure pump is anticipated to have a control panel, which monitors diesel engine operating conditions, rpm, and grouting pressure. Instrumentation at the control panel is also anticipated to measure the number of revolutions expended during grout injection of a specific hole for injected grout volume reporting. Additional instrumentation at the control panel is also anticipated as delineated in EDF-4933, "OU 7-13/14 In Situ Grouting Project Measurement and Controls."

For safety reasons, an operator shall be in attendance at all times during high-pressure pump operation to monitor pumping pressure or excessive vibration. The controls for the grout pump shall be designed to automatically shut off the grout pump when the line pressure exceeds the maximum operating pressure of 8,000 psi.

7.2.5 High-Pressure Retaining Components

The high-pressure retaining components (such as valves, flowline piping, hammer unions, integral union connections, manifolds, steel hose loops, and swivel joints) shall be designed and tested for a nonshock cold working pressure of 10,000 psi. Internal threads on the high-pressure retaining system are limited to 1/2-in. NPS in accordance with API Specification 6A, Paragraph 4.2.1.b.

7.2.6 High-Pressure Relief Devices

The subcontractor shall provide system pressure relief capability that shall ensure the pressure does not exceed ASME code requirements for a 10,000-psi maximum allowable working pressure. Pressure relief discharges shall be contained or directed safely away from personnel to ensure personnel and environmental safety. The grout pump shall automatically shut off when the emergency relief valve opens. There shall be no valves or restrictions between the pump discharge and the pressure relief devices.

The high-pressure pump shall have an integral externally adjustable emergency relief valve and manual bleed bolt. The discharge piping shall have a remotely operated bleed valve and rupture disk. This safety equipment is considered part of the engineered controls as recommended in EDF-4897 and DOE/ID-10968. The remotely operated bleed valve and manual bleed bolt provide a redundant method to relieve system pressure in the hose and fittings when the pump is shut off. The bleed valve and bolt will allow zero energy verification of the system before maintenance.

All relief devices shall have a certified capacity determined in accordance with ASME Code, Section VIII, Division 1, Paragraph UG-133, which exceeds the pumping capacity of the high-pressure pump at the maximum operating pressure of 8,000 psi. The safety relief valves and rupture disks shall have the a certification of capacity in accordance with ASME Code, Section VIII, Division 1, Paragraph UG-132. The relief set points shall be in accordance with ASME Code, Section VIII, Division 1, Paragraph UG-134, as follows:

- Integral adjustable emergency relief valve set pressure = 8,800 psi or 110% of operating pressure
- Rupture disc burst pressure = 10,500 psi or 105% of maximum allowable working pressure.

7.2.7 High-Pressure Hoses and Fittings

The pressurized grout hoses and fittings from the discharge of the grout injection pump up to and including the swivel are anticipated to be new, not previously used parts. The factory seals are normally on the ends. The hose handling equipment (i.e., hose reels and hose attachments on the drill rig) should be designed to prevent hose bending in excess of the manufacturer's minimum bend radius. The hose and end connections shall have a rated working pressure of 10,000 psi and should have been subjected to a hydrostatic pressure test of 15,000 psi in accordance with API Specification 17J/17K, Section 9.3. End connections are anticipated be hammer unions in accordance with API RP 17B, Section 4.3.3 or 4.5.4. Pipe threads are not acceptable on end connections. Hydraulic fittings (Society of Automotive Engineers) are not anticipated to be used in the high-pressure grouting system.

Caution shall be taken during design because it is possible for some fittings with different working pressure ratings to be screwed together. All fittings of the same size and style that could be screwed together shall have the same working pressure rating to avoid dissimilar pressure ratings.

7.2.8 Hose Restraints, Whip Checks, Bend Restrictors, and Hose Reels

Whip socks (i.e., Chinese fingers) with clevises shall be provided at all hose connections to prevent a whipping hose in case of hose connection failure. If a hose is connected to another hose, the hose sock clevises shall be connected together. If the hose is connected to equipment, the clevis shall be connected to the equipment. These hose socks and clevises shall be designed to restrain a force equal to that created by a liquid jet, diameter equal to the fitting internal diameter, spraying water at 15,000 psi.

Bend restrictors should be installed where bending in excess of the hose minimum bend radius (approximately 39 in.) could occur, such as the connection at the swivel. Bend restrictors should comply with API RP 17B, Section 4.5.3. Hose reels, if used, should be designed and installed in accordance with API RP 17B, Section 10.5.2.

Hose management equipment and methods are to be determined by the subcontractor.

7.2.9 Equipment Guards

Equipment guards are required at any connection or fitting that does not meet API design code or equivalent code requirements to prevent personnel injury should the connection or fitting fail. These connections and placement of equipment guards shall be approved by the contractor on a case-by-case basis.

7.2.10 Drill Pipe

The drill pipe is anticipated to be new, approximately 3.5-in. outside diameter (OD), with a minimum yield strength and minimum wall thickness as required for a minimum of 13,800-psi internal pressure (API RP 7G, Table 3), and with integral welded tool joints. The drill pipe should have die-stamped or paint-stenciled markings in accordance with API Specification 5A. Thread protectors are needed for the box and pin of tool joints to prevent damage while the pipe is being moved or stored.

The drill pipe length will be the length required to give the drill rig a capability of drilling to a depth of 25 ft below the ground surface. The drill pipe length will vary depending on lengths of the drill stem elements and height of the drill mast.

The drill stem diameter of 9 cm (3.5 in.) was proven to perform adequately in prior demonstration tests at the INEEL (INEEL/EXT-02-00233, Paragraph 2.1).

Drill pipes are anticipated to be stored in the drill string parts box located on the high-pressure grout pump semi trailer.

7.2.11 Drill Pipe Tool Joints, Drill Stem Subs, and Drill Stem Swivels

The drill pipe tool joints are anticipated to combine API threads with O-rings to prevent leakage. The tool joint design selected by the subcontractor may be a proprietary design; however, the threads should be inspected to the requirements of API Specification 5A. All parts of the drill stem—with exception of the drill bit, which enters the soil waste matrix—is anticipated to be a constant OD. Drill pipe “joiners,” which are short pieces of drill pipe with tool joints are not anticipated.

The box and pin threads of the tool joints should be thoroughly cleaned and a thread compound applied before making up the tool joints. If the threads become dirty, they should be cleaned. In a good connection, the seal between the two parts is made between the shoulders of the pin and box. The shoulders, which seal the joint because of preload, should be cleaned and inspected to avoid leaks. Normal API-threaded tool joint connections have tapered shoulders that help align the drill stem elements as they are threaded together. A saver sub at the bottom of the swivel may be needed to keep from wearing out the threads on the bottom of the swivel. To ensure thread integrity, drill stem tool joint threads should be inspected periodically in accordance with API 7, Sections 10 and 11.

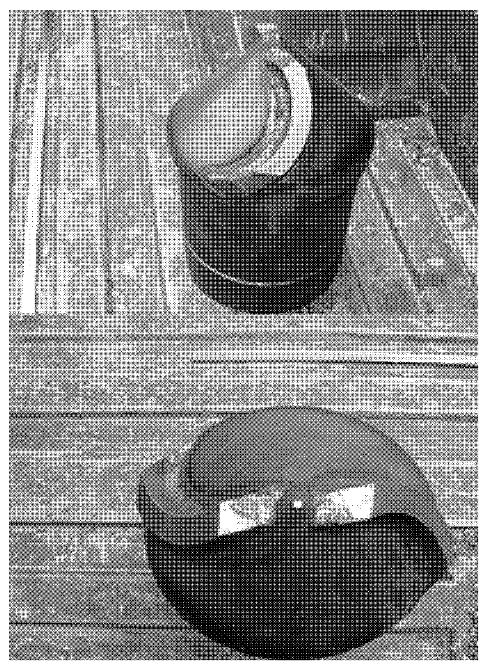
7.2.12 Drill String Wiper

A double wiper assembly will be used for drill stem contamination control as detailed in EDF-5153, "OU 7-13/14 In Situ Grouting Project Hydraulic Excavator and Drill-Injection Rig."

7.2.13 Drill Bit with Nozzles

The drill bit is anticipated to be a hollow tapered point, with an API-threaded joint and two jets (180° apart) or three jets (120° apart) that are separated vertically. The bit wall thickness should not be less than the drill pipe wall thickness. The drill bit may be tapered, beginning with approximately 3.5-in. OD at the tool joint and tapering to an approximately 3.0-in. OD at the jets to minimize grout flow up along the drill stem. The bit is anticipated to be designed with a cavity below the grouting jets to allow heavy or large particles to collect there. The drill bit is anticipated to be a special fabricated piece designed with three grouting jets. The diameter would be the same as the drill stem, tapering to a conical shape at the end. Drill bits are anticipated to be stored in the drill string parts box or the bit change box. Drill bits may be repaired; however, this work is anticipated to be performed by the subcontractor offsite at a machine shop.

The bits for drilling through hardpan need to have two flutes welded to the exterior of the bit to facilitate the drilling process (see Figure 2). Drilling through hardpan during the beryllium block grouting project proved very difficult and time consuming using a tapered drill point without the flutes. Jets will use 1/2-in. nominal size API or pipe threads as determined by the jet manufacturer. The jets are anticipated to have a nozzle size of 2.4- to 3-mm diameter. The nozzles shall be pointed downward at a 15-degree angle from horizontal for personnel safety. If the jets sprayed out horizontally, the potential exists that personnel in the proximity of the drill bit could be sprayed with high-pressure grout. The drill bit should be designed so the grout injection nozzles do not drain on the drill rig breakout tool when the bit is removed from the drill string. The jets may have to be tack welded to the drill bit to prevent them from vibrating loose, as experienced during beryllium block grouting. If jets have been tack welded to prevent them from vibrating loose, the weld must be ground out before changing jets and retack welding. A weld repair procedure for this work must be submitted by the subcontractor and approved by the contractor before this operation.



Jets will need a hexagon socket for changing the jets using an Allen wrench. Upon installation, the jets will be torqued to the torque for the thread type and size as recommended by the jet manufacturer. Jet wear may be measured using wire gauges.

Misalignment is not allowed for installing jets. Dirt must be cleaned from the tapped hole before installing new jets to prevent thread damage and jamming.

7.2.14 Diesel Generator

A diesel generator is anticipated at each drill rig to provide power required for the electrical equipment located at the drill rig. The electrical equipment requiring power includes, but is not limited to, a pressure washer (approximately 5 hp), low-pressure clean water pump (approximately 2 hp), low-pressure hopper grout pump (approximately 20 hp), and oil field mud screen (approximately 3 hp). The hydrotest pump, located in the bit change box, will also require electrical power; however, it is not anticipated to be operating at the same time as the other equipment. A 40- kW diesel generator is anticipated at each drill rig for power related to the auxiliary equipment. If power is also required for temporary office-type facilities, the generator needs to be correspondingly larger.

7.2.15 Bit Change Box

A bit change box is anticipated at each drill rig, which will contain a new bit, cleanout manifold, and hydrotest fixture. The bit change box should be designed so that the drill stem may be inserted and torqued into any of these three items. A cleanout water tank needs to accompany the bit change box and be mounted on the truck bed (see Appendix A).

EDF-5155, Section 7.2.8 provides instructions for cleaning the bits.

7.2.16 Spare Parts

Spare parts should be provided and stored as recommended in the various manufacturers' operating and maintenance manuals. The spare parts should be like-for-like replacements. A spare parts list shall be submitted for approval according to the vendor data schedule.

8. QUALITY CONTROL

8.1 Low-Pressure System Quality Requirements

Quality requirements for the low-pressure portion of the grout delivery system should be in accordance with DOE-ID Architectural Engineering Standard 1540, *Piping General Requirements*. The low-pressure system piping shall be designed in accordance with ASME B31.3 and vendor standards. All pressure retaining components shall be manufactured in accordance with the standards listed in ASME B31.3, Table 326.1.

Certificates of compliance shall be submitted for any material used in pressure-containing piping components and shall state that the material conforms to the listed specification. Unlisted materials may be used provided contractor approval is obtained before purchase. Certificates of compliance for all weld filler materials shall be submitted as vendor data. Materials of unknown specification shall not be used for pressure containing piping components.

The following vendor data will be required to be submitted and approved before purchase:

- Catalog cuts and product data for all low-pressure system equipment (such as valves, pumps, instruments, tanks, and specialty items)

- Product data for pipe insulation, insulation jacketing, and installation instructions

- Thermoplastic piping (i.e., polyvinyl chloride) bonding procedure test assembly results and performance qualifications for each bonder

- Pressure test procedures and pipe flushing procedures

- Sterilization procedure for potable water piping, if any.

Field welding and examination of all pressure piping and pipe supports shall be performed in accordance with the INEEL Welding Manual. Offsite shop welding shall be performed in accordance with American Welding Society (AWS) Standard D1.1, *Structural Welding Code,* for carbon steel, AWS Standard D1.2, *Structural Welding Code Aluminum,* and AWS Standard D1.6, *Structural Welding Code—Stainless Steel*. Welding procedures and welder qualifications for onsite welding shall be in accordance with the INEEL Welding Manual. Welder qualifications for personnel performing onsite welding and a letter listing the onsite welding procedures to be used shall be submitted for approval.

8.2 High-Pressure System Quality Requirements

The API provides guidance in the form of product specification levels (PSLs) for manufactures and purchasers of pressure-retaining components to ensure the components meet the design and manufacturing requirements as specified in the API specifications. Based on a minimum-rated working pressure of 10,000 psi, PSL-2 will be applied to the ISG Project as listed in API Specification 6A, Appendix A, Table A2.

8.2.1 Records to be Furnished to the Purchaser by the Manufacturer

Required records shall be legible, identifiable, retrievable, and protected from damage, deterioration, or loss. Records shall be signed and dated.

The records required by the applicable API specification, or equivalent specification—including, but not limited to, records listed below—shall be kept on file by the subcontractor for inspection by the contractor:

- Certificate of compliance stating the equipment and components conform to the current edition of the applicable API, or equivalent, specification

- Material traceability records for metallic pressure-retaining components

- Pressure test records, which shall identify the actual test performed, holding period, and recording devices, and which shall be dated and signed.

8.2.2 Equipment or Component Marking and Serialization

Marking shall be as specified in the applicable API, or equivalent, specification (i.e., API RP 17B, Section 10.4; API 6A, Section 8; API 7, various sections). Individual components and assemblies shall be assigned and marked with a unique code to maintain traceability and associated records. Some items (such as test and gauge connections) do not require marking.

8.2.3 Pressure Design Verification Report

The subcontractor shall verify and document that all pressure-retaining system components are assembled, tested, and marked and have material traceability per the API, or equivalent, specifications and manufacturer's recommendations for the rated pressure before use and any time the pressure system has been modified. Verification of compliance with the requirements shall be provided in the pressure design verification report. The subcontractor shall also verify that the system pressure relief equipment functions as designed.

8.2.4 High-Pressure Component Inspection

The grout hose shall be inspected in accordance with the manufacturer's recommendations and, at a minimum, as follows:

- Daily visual inspection for flattening, excessive bending, or twisted hose
- Routine (monthly minimum) visual inspection of outer sheath, connection-to-end fittings, damaged seal area, coating, end fitting bore damage, corrosion, cracks, and abrasion
- Quarterly visual inspection of entire external sheath and endoscopic inspection of entire internals
- If the hose is not replaced annually, an annual field hydrostatic pressure test at 15,000 psi for 6 hours.

When the hose is replaced, destructive testing shall be performed on the removed hose to determine interior hose condition and end fitting wall thickness thinning.

High-pressure components shall be inspected in accordance with the manufacturer's recommendations. At a minimum, quarterly visual inspections shall include inspection for exterior damage and inspection of interior sealing surfaces for fittings that are readily accessible.

Field repair shall not be performed on high-pressure retaining piping components. Repair or remanufacturing of piping components shall only be performed by the component manufacturer. Pumps, swivels, and drill string components may be field repaired in accordance with vendor instructions. Field replacement of any pressure retaining component may be performed by the subcontractor.

Drill stem elements shall receive quarterly visual inspection for cracks in the outside of the drill stem in accordance with API RP 7G, Section 13.2.2. Quarterly visual inspection of tool joint shoulder condition, thread condition, and box swell and/or pin stretch (indicating over-torquing) shall be performed in accordance with API RP 7G, Section 13.3.2.

8.2.5 Product Data, Catalog Cuts, and Operating Manuals

The subcontractor shall submit product data and catalog cuts for all materials as vendor data. Operating manuals for safety valves, valves, and equipment shall also be submitted as vendor data.

8.2.6 Contractor Oversight

Surveillance will be performed by the contractor's inspectors to verify the following:

- Compliance of the work to the specifications

- Required examinations and tests are being performed
- Required material and testing documentation is on file.

9. RISKS

9.1 Equipment and Material Availability

9.1.1 Equipment Lead Time

Equipment, such as the high-pressure pump and drill rig, may have a six-month or more lead time. It is recommended that, for the first year, the subcontractor be allowed to procure used units if this turns out to be a problem and the used units are available. However, the RFP should specify new units.

9.1.2 Equipment Longevity

High grout flow velocity in the high-pressure hose and fittings will wear out the hose and fittings more quickly, especially with sand in the grout mix. As a general rule, flow velocity for water should be maintained below 10 ft/second and flow velocity for grout should be approximately 3 ft/second (per Ernie Carter, Carter Technologies Company). Each grout pump will be pumping approximately 50 gallons/minute (EDF-5135, Appendix A). This flow rate equates to 4.8 ft/second velocity in a 2-in. inside diameter (ID) hose, 7.9 ft/second velocity in a 1-½-in. ID hose, and 18.6 ft/second in a 1-in. ID hose. Based on these flow rates, the 1-in. ID hose is too small, and wear and line losses would be unacceptably high. The subcontractor must weigh the cost of replacing hoses because of abrasion versus line size for selecting the desired cementing hose size. The hose must be rated for cementing service, not hydraulic service as stated in Sections 4.3 and 7.1.4. It is anticipated that the vendor will choose a 2-in. hose, which is about the minimum acceptable size based on velocity. The 10,000-psi working pressure rated cementing hose of this size has an OD of approximately 4.8 in. and weighs 18.0 lb/ft[a] making hose management an important aspect. Hose management equipment and methods will be determined by the subcontractor.

9.2 Safety

9.2.1 Air Entrained in High-Pressure Lines During Leak Test

The water flow rate from the hydrotest manifold in the bit change box to the vent plug at the high-pressure pump should be high enough to purge the lines before the leak test. The leak test procedure submitted by the subcontractor shall include the requirement that all air is vented.

9.2.2 Plugging Jets

Using the shaker screen on the grout receiving hopper and the duplex strainer in the high-pressure pump suction line should minimize jet plugging. If one of the strainer baskets becomes plugged, the operator can immediately switch to the other strainer, followed by cleaning of the plugged strainer.

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[a] Hose size and weight information is based on e-mails from Drew Garrow and Dick Betteridge of RB Pipetech, LTD, Newcastle England to Al Cram, BBWI, dated July 23, 2004 and August 4, 2004.

9.2.3 Fittings of Different Ratings Being Connected Together

See Section 7.2.7.

9.2.4 Leakage at the Bit Rotary Shouldered Connection

See dynamic testing as detailed in EDF-5155, Section 7.2.4.

9.2.5 Overpressure in the High-Pressure System

This condition is highly unlikely since the pump will have an integral externally adjustable emergency relief valve and manual bleed bolt. The discharge piping shall have a remotely operated bleed valve and a rupture disk. These engineered safety features will minimize the likelihood of an overpressure event.

10. LOGISTICS SUPPORT

The logistics support for the grout delivery portion of the system includes the following:

- An area just inside of the SDA fence next to the grout agitator tank (located outside of the SDA fence) for the ready-mix truck cleanout water tank and grout loading of the ready-mix trucks. This area will need to be built in a manner that does not block the access road along the south side of the SDA. A proposed loading layout is shown on EDF-5135, Appendix B, “ISG Storage and Mixing Flow Diagram,” Sheet 2.

- Capability to deliver clean water to each 500-gal clean water tank located near each of the three grout receiving hoppers and to each ready-mix truck located in the SDA for cleanup between each truck load of grout.

- Capability to remove and disposition the cleanup water that will be collected in the cleanup water tank located next to the bit change box on the 1-ton truck.

- Diesel fuel delivery to each high-pressure grout pump (approximately 450 hp), each diesel generator located on the hopper lowboy trailer, and the 1-ton trucks that carry the cleanup water tanks and bit change boxes.

- Additional radiological control surveillance, if required by Radiological Control personnel, at the south gate for surveying the ready-mix trucks during entry and exit if the subcontractor decides to build the batch plant offsite. Currently, the delivery trucks do not require surveying since they do not enter the radiological buffer area around the drill rig. The grout pump is located outside of the radiological buffer area.

- Electrical power for grout delivery equipment (such as receiving hopper pumps, vibratory screens, and high-pressure hand washers) will be provided by a diesel generator mounted on one of the lowboy trailers that will be moved along with each drill rig. The drill rig engine generator will provide power for instrumentation mounted on the drill rig. An external power source strung across the SDA to each drill rig is not anticipated.
- Spare parts and consumables that are anticipated to be needed frequently (such as shaker screens and extra drill bits with jets) will be located in the drill string parts box that will be moved along with the drill rig. Parts (such as an extra mast with drill motor) will be located on a semi-trailer that will be readily available for immediate use should the need arise.

11. RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

The ISG grout delivery subsystem is physically feasible and the components are readily available. All components of the grout delivery subsystem are off the shelf or can be commercially fabricated to perform the grouting rate as determined per calculations of EDF-5135, Appendix A.

The low-pressure components are all commercially available and only require certificates of compliance. High-pressure injection pumps are available in the required capacity per discussions with vendor representatives and review of vendor catalogs.

The oil field-type mud screen for the grout receiving hopper is commercially available. The grout receiving hopper may be a special fabrication order because of the minimum pressure rating for the integral pump. This pump must be capable of maintaining a 50-psi minimum at the high-pressure pump inlet.

High-pressure valves, hoses, hammer unions, line piping, fittings, and loose connections are available in accordance with national consensus codes. These piping components shall require material traceability, certificates of compliance, and hydrostatic test reports to handle the 8,000-psi required operating pressure. The drill stem, including the swivel, subassemblies, drill pipe, tool joints, and drill bit are available, although the drill pipe may be a special fabricated length.

It is recommended that the criteria in this EDF be used as a basis for writing a performance-based specification for the ISG Project. For safety reasons and to comply with DOE Order 440.1A, Attachment 2, Section 20.c, *Pressure Safety*, the performance-based specification should list the design code compliance and quality requirements delineated here as mandatory. Other aspects of the proposed design may be deviated from; however, bidders should be required to submit their desired deviations with their bids and officially request a deviation before contract award.

12. REFERENCES

API RP 7G, *Recommended Practice for Drill Stem Design and Operating Limits*

API RP 17B, *Recommended Practice for Flexible Pipe*

API Specification 5A, *Specification for Casing, Tubing and Drill Pipe*

API Specification 6A, *Specification for Wellhead and Christmas Tree Equipment*

API Specification 7, *Specification for Rotary Drill Stem Elements*

API Specification 16C, *Specification for Choke and Kill Systems*

API Specification 17J, *Specification for Unbonded Flexible Pipe*

API Specification 17K, *Specification for Bonded Flexible Pipe*

ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, *Rules for Construction of Pressure Vessels, Alternative Rules*

ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, *Rules for Construction of Pressure Vessels*

ASME Code B31.3, *Process Piping*

AWS Standard D1.1, *Structural Welding Code*

AWS Standard D1.2, *Structural Welding Code Aluminum*

AWS Standard D1.6, *Structural Welding Code - Stainless Steel*

DOE-ID Architectural Engineering Standard 1540, *Piping General Requirements*

DOE Order 440.1A, "Worker Protection Management for DOE Federal and Contractor Employees"

DOE Order 414.1B, "Quality Assurance"

DOE/ID-10968, "Type B Accident Investigation Board Report, Grout Injection Operator Injury at the Cold Test Pit South"

EDF-4013, "Feasibility Study Technical and Functional Requirements for the OU 7-13/14 In-Situ Grouting Preliminary Documented Safety Analysis"

EDF-4933, "OU 7-13/14 In Situ Grouting Project Measurement and Control"

EDF-4897, "Evaluation and Response to the Grout Accident Investigation Report for the OU 7-13/14 Early Actions Beryllium Encapsulation Project"

EDF-5135, "OU 7-13/14 In-Situ Grouting Project Grout Storage and Mixing"

EDF-5146, "OU 7-13/14 In-Situ Grouting Project Grout Selection"

EDF-5155, "OU 7-13/14 In Situ Grouting Project Operations, Maintenance, and Logistics"

GDE-51, "Construction Project Management"

INEEL/EXT–02-00233, *Final Results Report, In Situ Grouting Technology for Application in Buried Transuranic Waste Sites*

INEEL/EXT-03-00316, *Feasibility Study Preliminary Documented Safety Analysis for In Situ Grouting in the Subsurface Disposal Area*

International Building Code, 2003 Edition, International Code Council, http://www.iccsafe.org/

ISO 10423, *Petroleum and Natural Gas Industries – Drilling and Production Equipment – Wellhead and Christmas Tree Equipment*

PRD-320, "Pressure System Safety"

TFR-267, "Requirements for the OU 7-13/14 In Situ Grouting Project (Customer, Project, and System)"

TFR-269, "Requirements (Assumptions) for the OU 7-13/14 In Situ Grouting Project"

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Appendix A

In Situ Grouting Grout Delivery Flow Diagram

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Appendix A

In Situ Grouting Grout Delivery Flow Diagram